ANALOG DEVICES

AB-107
APPLICATION NOTE

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Two-Wire, 4–20 mA Current Transmitter

by James Wong

This two-wire current transmitter provides an output of 4mA to 20mA that is proportional to an input voltage V_{IN} plus an offset. Current loops are particularly useful in process control systems where remote analog signal conditioners must be interfaced to a central location. The loop can be powered by an inexpensive, unregulated DC voltage. The low supply current needs of the OP-22 programmable op amp and REF-02 bandgap reference allow for "floating" operation. The transmitter circuit uses less than 2mA and can therefore supply up to 2mA at 5V as a transducer reference or bridge supply without exceeding the minimum loop current of 4mA. The OP-22 and REF-02 can be operated over a wide supply range. With a load resistor R_L of 50Ω and a sense resistor R_S of 100Ω, the maximum voltage from Ground to Signal Common is 150Ω × 20mA, or 3V. The REF-02 minimum limit is 7V, therefore V_S needs to be above 10V.

The OP-22 regulates the output I_O to satisfy the current summation at the noninverting mode:

$$\frac{V_{IN}}{R_1} + \frac{5V}{R_2} - \frac{I_O R_S}{R_3} = 0$$

$$I_O = \frac{1}{R_S}\left(\frac{R_3}{R_1} V_{IN} + \frac{R_3}{R_2} 5V\right)$$

As a design example, consider a system need for:

$$I_O = \frac{16V_{IN}}{100\Omega} + 4mA$$

This would provide an output span of 4mA to 20mA for an input range of zero to 100mV. This requires a ratio of 16 for R_3/R_1, and a ratio of 0.08 for R_3/R_2. Choosing R_1 to be 5kΩ, then we need $R_3 = 80k\Omega$ and $R_2 = 1M\Omega$. Drift due to input bias current of the OP-22 can be minimized by making R_4 equal to the parallel combination of R_1, R_2, and R_3.

Designing for other input ranges or other values of R_S and R_L is straightforward. The sense resistor R_S does have an upper limit that is not obvious; the voltage drop across R_S at turn-on can pull the OP-22 noninverting input negative relative to its own negative supply rail. This can cause the OP-22 op amp output to go for the positive limit which drives Q1 into saturation and a possible latching condition. This is prevented by limiting the negative voltage at the noninverting input or by limiting the maximum drop across R_S.

This current transmitter has excellent linearity, operates well with very low supply currents, and is easily adaptable to a wide range of input signal levels.